2

Philosophy and Definitions

Rhode Island, as other states throughout the nation, is setting higher expectations for student achievement. Students should graduate from high school with the skills, knowledge, and motivation to succeed in life and work. Unless we set high standards for all children, and give each one the support they need to achieve those standards, we will not be educating all our students. If our children are to be healthy and productive citizens, they must receive the education and practice in the skills necessary for future success.

Setting high learning standards raises the expectations of all people involved in our educational systems - students, parents, teachers, administrators, and the business community. New methods of instruction and assessment must be established to successfully achieve the new higher learning standards. International and national competition requires that we train our people to use thinking skills more effectively.

"Student achievement must ultimately be the measure of accountability for schools."

Reaching for High Standards. Student Performance in Rhode Island, RIDE, 1994, p. 1)

Student performance should be assessed by both traditional and alternative methods. Individual student achievement should be monitored by work in ongoing projects, cooperating performance in group problem solving and by a portfolio of personal work.

The creation, dissemination, and implementation of subject matter curriculum frameworks is one set of structural changes needed to clarify and raise expectations for all students. The Science Framework for Rhode Island is intended as a document to be discussed among teachers, administrators, school boards, parents, business leaders, students, and the involved public. The goal of the document is to identify what students should know, perform, and value in science and technology.

This framework is designed to be continually evolving. It appears at a time when our children are faced with great social and economic challenges. According to the University of Rhode Island's Labor Research Center, Rhode Island is undergoing a transformation into a "mature third world economy," dependent upon tourism and low-wage manufacturing for its livelihood. Between 1982 and 1992, Rhode Island lost 28,500 manufacturing jobs from a base of 166,600 positions in manufacturing. From June, 1990 to June, 1992 alone, the state eliminated 40,600 jobs overall, touching every major employment category except service industries and government.

If Rhode Island is going to reassert its position within national and global economies, higher order thinking skills and knowledge associated with the scientific enterprise are critical. Rhode Island students must have a broad scope of science knowledge and proficiency in the use of technical tools in science learning. They also must be competent in the problem solving skills required by the scientific endeavor. Approximately seventy percent of all jobs by the year 2000 will not require a four-year college degree. It is vital that all students receive effective education in the knowledge and application of science concepts, principles, and practices. This framework speaks to the benchmarks of science learning for all students.

"To meet the challenges of these high performance work places, workers need to know how to read, write, and communicate clearly, perform mathematical calculations, think critically, work as members of a team, take responsibility for quality, inventories, and productivity, solve problems and make decisions. This is a departure from the expectations managers have had of workers under mass production -- and from the skills many of our workers possess today."

... Rhode Island's Choice: High Skills or Low Wages, RI Skills Commission, May 1992.

Science is a particular way of learning about, looking at, and knowing the world (Brown, 1994). Science includes:

* asking questions about how the world works

* collecting and analyzing relevant data

* formulating ideas which draw upon the work of others, both past and present

* testing these ideas through prediction and controlled experiments

* communicating the results of one's labor to colleagues around the world for their critique and further refinement

* developing a frame of reference and general disposition toward investigations of the natural world which can be thought of as "habits of mind and affect"

* examining the implications of scientific discoveries on social, economic, and political systems

"The irony is that children start out as natural scientists, instinctively eager to investigate the world around them. Helping them enjoy science can be easy. There's no need for a lot of scientific jargon or expensive lab equipment. You only have to share your children's curiosity."

Mary Budd Rowe, Professor of Science Education, Stanford University in "Teach Your Child to Wonder," Reader's Digest, May 1995, p. 178)

Explanatory frameworks for the natural world that prove fruitful to practicing scientists are accorded the status of theories. Theories are considered temporary and are therefore continually retested and revised (for example, theories of an earth-centered

"No nation can produce a highly qualified work force without first providing its citizens with a strong general education. All of our young people should start with a solid foundation of knowledge, whether or not they pursue a university degree. We need to set high standards that have real value and insist that virtually all students meet them."

... Rhode Island's Choice: High Skills or Low Wages, RI Skills Commission, May 1992.

versus a sun-centered universe). Thus, science is a never ending quest to explain the natural world.

The focus of **science education** is not only to produce future scientists. Rather, the preeminent goal is to help all students, as learners and future citizens within a democracy, to be scientifically literate (Matthews, 1994). Scientific literacy includes "being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; understanding some of the key concepts and principles of science; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises, and know what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes." (Rutherford and Ahlgren, 1990: x). Literacy entails more than head knowledge. It also involves the ability to design and carry out experiments and investigations of the natural world (Hegarty-Hazel, 1990). It includes communicating those results to others in meaningful ways and relating knowledge of science principles to concrete examples in one's everyday life and the world of work.

Science is a field which is not exclusive of ethics. However, ethics are often not incorporated into the process of 'doing science.' Increasingly, because of the use of advanced technologies in scientific fields, individuals need to make complex decisions both in the work force and in everyday living. Students need to understand that ethics and science go hand in hand. A few discussion topics might be: "Is dissection necessary in the classroom or can computer simulations be used?" or "What are the ethics involved in an environmental issue - such as cutting down forests to meet our necessary need for paper?" Diminishing resources and increasing environmental problems world-wide mean teachers must be vigilant in providing students with a strong ethical base on which to make decisions.

"Constructivism does not claim to have made earth-shaking inventions in the area of education; it merely claims to provide a solid conceptual basis for some of the things that, until now, inspired teachers had to do without theoretical foundation."

Ernst von Glasersfeld, "A Constructivist Approach to Teaching," Constructivism in Education, Eds. L.P. Steffe, J. Gale, Hillsdale, NJ: Lawrence Erlbaum Associates, 1995, p. 15

One area where scientists currently have to make such decisions is in the field of genetic engineering. The recent discovery of a 'fat' gene raises an ethical dilemma. Is it appropriate for scientists to create a drug which can eliminate fat? Increasingly scientists are aware of the complexity of interactions which occur in ecosystems and between species. Future generations must learn that they are one piece of a vast global system and are dependent upon it for their health and well-being.

The latest knowledge of how children learn should be incorporated into the science education experiences and materials for K-12 students. K-12 instruction should introduce students to science concepts and theories with a gradual spiral of increasing levels of abstraction. One example of this approach is the Scope, Sequence and Coordination Project of the National Science Teachers Association (1992, 1993). Concepts, principles and theories should be carefully sequenced according to the cognitive level of the student's existing science knowledge. Instruction should also be designed so that students may construct and create a personal knowledge of science relative to themselves and their environment. This approach to learning is **constructivism.** The theory maintains that the central purpose of learning is to make a personal meaning of the reality which surrounds you (Tobin, 1993; Shapiro, 1994; Fensham, Gunstone and White, 1994; Steffe and Gale, 1995). This includes:

* linking new knowledge to existing knowledge

* reframing one's own understanding in light of new evidence

* testing one's ideas in new contexts to see whether they are valuable in investigating and explaining phenomena

Approaching science teaching in a Constructivist framework requires adoption of a "less is more" position regarding the science curriculum. It is better that students experience a few concepts, principles and their applications in depth than that they march through material to "finish" a textbook. Teachers and science supervisors must balance the need for a broad conceptual framework in science with the need for adequate time within the science curriculum for students to construct personal meaning of scientific ideas and to test their ideas in various ways (Black and Lucas, 1993).

A number of principles formulated by the National Committee on Science Education Standards and Assessment are adapted here as key assumptions for the Rhode Island Science Framework. They are:

* *All students, regardless of gender, cultural, linguistic or ethnic background, physical or learning disabilities, aspirations, or interest and motivation in science, should have the opportunity to attain higher levels of scientific literacy than they do currently. This is a principle of equity.*

* *All students will develop science knowledge as defined in the content standards and an understanding of science that enables them to use their knowledge as it relates to scientific, personal, social, and historical perspectives.*

* *Learning science is an active process.*

* *Resources, such as time, personnel, and materials must be devoted to science education.*

"Autonomy and initiative prompt students' pursuit of connections among ideas and concepts. Students who frame questions and issues and then go about answering and analyzing them take responsibility for their own learning and become problem solvers and, perhaps more important, problem finders."

Jacqueline G. Brooks, Martin G. Brooks, The Case for Constructivist Classrooms, Association for Supervision and Curriculum Development, Alexandria, VA, 1993, p. 103.

"The integration of curriculum may be accomplished along a continuum ranging from artificial subject matter divisions present in the current curriculum through multi- or trans-disciplinary curriculum in which the curriculum cuts across many areas and is more like what a student will encounter outside of school."

... Educating ALL Our Children. A Report of the 21st Century Education Commission, March 1992.

* *Greater emphasis must be given to critical concepts, rather than presenting a general overview of many topics.*

* *School science must reflect the intellectual tradition that characterizes the practice of contemporary science.*

* *Improving science education is part of systemic education reform.*

The science benchmarks presented in this document are adopted or adapted from Project 2061, a long-term educational reform initiative of the American Association for the Advancement of Science. Over the past decade, hundreds of scientists, mathematicians, engineers, social scientists, teachers, and administrators have collaborated to produce both a general guide to science education (Science for All Americans) and a provisional guide to science learning goals (Benchmarks for Science Literacy). Project 2061's vision for education reaches far beyond the "traditional" sciences to embrace mathematics, technology, the arts, and the social sciences. The RI science framework concentrates solely on selected benchmarks related to the sciences and the nature of technology. By no means should the reader infer that these are the only important benchmarks. Rather , school districts and teachers are encouraged to read and contemplate the other dimensions of the Project 2061 framework for its suitability in guiding reform efforts throughout the K-12 curriculum. *Benchmarks* as used in this document and in *Project 2061*, *"specifies how students should progress toward science literacy, recommending what they should know and be able to do by the time they reach certain grade levels." (AAAS, 1993: xi)*

The science benchmarks presented here delineate key concepts, principles, knowledge, and skills that all students should know and be able to do. We have purposely not completed our work with the benchmarks related to the sciences drawn from chapters 4 - 6 of the Benchmarks for Science Literacy. We invite you, our reader, to:

* join with colleagues and create additional pages drawing upon Project 2061 benchmarks

* amend our pages with alternative activities, assessment ideas, other process focus suggestions

* contribute short vignettes of one or two paragraphs linked to specific benchmarks which tell other Rhode Islanders how your school or classroom is addressing particular benchmarks, using assessment strategies, applying educational technology, modifying curriculum or practices to meet the needs of specific groups of students, and pioneering new instructional strategies.

The benchmarks presented here are not exhaustive, but are sufficient in the Development Team's view, to catalyze local curriculum development and instructional practices. No one curriculum is ideal for achieving these benchmarks nor is there one set of instructional practices which guarantees success for all students. Rather, school districts and teachers are expected to tailor their own curriculum and instructional practice to ensure that all students are afforded equitable opportunities to learn and experience science. For some students this will take a more applied, practical approach -- others will benefit from a more conceptually based approach. Some students will progress quickly through certain benchmarks, others at a slower pace.

All students should not just read about the sciences -- they must do science. The excitement that characterizes the enterprise of science should be experienced by every student as they seek in the company of their peers to make meaning of the natural world. Science experiences should also connect students to everyday life and the science- and technology-related social issues with which local communities, states, nations, and humanity struggle (Cheek, 1992; Aikenhead and Solomon, 1994).

Students also need exposure to the world of technology and the ways in which technology shapes human life. Technology is undoubtedly one of the most pervasive features of the twentieth century world (Marcus & Segal, 1989; Nye, 1994; Pursell, 1995). It is also one of the oldest of human endeavors, predating science, for example, by thousands of years. In recent decades, the connection between technology and the sciences has grown considerably closer -- to the point where sometimes scientific discoveries push technological innovations or technological inventions aid scientific discoveries or challenge existing theories about how the world works. A practitioner working today in a large scale Research & Development operation often finds the day a seamless conceptual web as they integrate their knowledge of science and technology to solve challenging problems.

Most of us use the word "technology" in the course of everyday conversation in a variety of ways. Sometimes we mean a particular way of doing things, sometimes we refer to a particular object as a technology. A particular contemporary and narrow use of the word is as a referent for computers and their related devices (modems, hard drives, etc.).

Stephen Kline, Professor of Mechanical Engineering at Stanford University and a faculty member in the university-wide Values in Technology, Science and Society Program, reminds us that we can talk about **technology** in one of four ways (Kline, 1985):

* as an artifact or hardware (e.g., an aspirin, chair, building, computer, or videotape)

'It was a strange sight: a man, standing before a fountain, watching the falling water and tilting his head from side to side. Drawing closer, I saw he was rapidly moving the fingers of his right hand up and down in front of his face.

I was in the seventh grade, visiting Princeton University with my science class, and the man at the fountain was Albert Einstein.

For several minutes, he continued silently flicking his fingers. Then he turned and asked, "Can you do it? Can you see the individual drops?"

Copying him, I spread my fingers and moved them up and down before my eyes. Suddenly, the fountain's stream seemed to freeze into individual droplets. For some time, the two of us stood there perfecting our strobe technique. Then, as the professor turned to leave, he looked me in the eye and said, "Never forget that science is just that kind of exploring and fun."

Mary Budd Rowe, "Teach Your Child To Wonder," Reader's Digest, May 1995, p. 177

* as a methodology or technique (e.g., painting, using a microscope or pocket calculator)

* as a system of production (e.g., the automobile assembly line or an entire industry)

* as a sociotechnical system (an airplane, for example, suggests a plethora of interrelated devices, human resources, and artifacts such as airports, passengers, pilots, mechanics, fuel, regulations, and ticketing.)

"Since individual technologies and their networks enhance or undermine the people we want to be and the society in which we want to live, we as citizens must try to understand this mighty force and see it not only for what it is but also for what it might be."

C. Pursell, The Machine in America: A Social History of Technology, 1995, p. xii)

Technologies embody tradeoffs that are made between what is desired and real world constraints of cost, time, thought, energy, etc. (Wenk, 1986). This may mean that certain individuals, organizations, and social groups bear the costs and burdens while other individuals, organizations, and social groups derive benefits and profits. Even the same group will experience tradeoffs between conflicting objectives.

Another hallmark of technologies are unanticipated side effects (Westrum, 1991; Pursell, 1994). These are effects which cannot be accurately predicted in advance but emerge as the technology in question is implemented. Some of these side effects are positive in nature, some may be neutral, while others are decidedly negative.

Position papers endorsing the worth and importance of a science, technology and society (STS) approach to education have appeared from the National Science Teachers Association, National Council for the Social Studies, and the International Technology Education Association. The recently released curriculum standards for social studies (NCSS, 1994), the draft national science standards, and the Project 2061 Benchmarks all give attention to the importance of STS elements within school curriculum, especially in the sciences and the social studies. Technology has been the absent presence in the K-12 school curriculum. The technological world in which we live and in which our children will function demands greater attention to the role of technologies within society.

We look forward to your comments, suggestions, and revisions as we all engage in the process of setting new and higher standards for student achievement in the sciences. Members of the Development Team are available to meet with you and your colleagues to discuss this document, help you analyze your local curriculum, and to garner feedback for a second edition of this framework at some future point in time.

"Achieving the goal of scientific and technological literacy requires more than understanding major concepts and processes of science and technology. Indeed, there is a need for citizens to understand science and technology as an integral part of our society. Science and technology are enterprises that shape and are shaped by human thought and social actions."

Rodger W. Bybee and George E. DeBoer, "Research on Goals for the Science Curriculum," Handbook of Research on Science Teaching and Learning. Ed. Dorothy Gabel. Macmillan, NY 1994, p. 384).

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